Claim List

1. (currently amended) A laser providing a preselected wavelength beam comprising:

a) a laser resonator having a laser resonator cavity formed between a first laser resonator reflective surface and a second laser resonator reflective surface, said laser resonator having a resonator optical axis;

b) a lasing medium located within said laser resonator cavity for generating a fundamental wavelength beam;

c) an optical parametric oscillator (OPO) cavity formed between a first OPO reflective surface and a second OPO reflective surface said optical parametric oscillator cavity having an oscillator optical axis which is in part separate from said resonator optical axis and which in part overlaps said resonator optical axis;

d) an~~a~~ ~~nonlinear~~OPO nonlinear generator for OPO generation located within said OPO cavity along said oscillator optical axis and along said resonator optical axis in optical communication with said first and said second OPO reflective surface;

said ~~nonlinear~~OPO nonlinear generator oriented to convert said fundamental wavelength beam into a preselected wavelength beam having a preselected longer wavelength than said fundamental beam;

e)   means to direct said fundamental wavelength beam into said optical parametric oscillator cavity along said oscillator optical axis and through said ~~nonlinear~~OPO nonlinear generator at a preselected polarization to convert a first portion of said fundamental wavelength beam to a preselected wavelength beam having a longer wavelength than said fundamental beam, said preselected wavelength beam having the same preselected polarization as said fundamental beam;

f)   said optical axes intersecting opposed faces of said ~~nonlinear~~OPO nonlinear generator;

said opposed faces having a Brewster cut at the intersection of said ~~nonlinear~~OPO nonlinear generator and said axes so that the fundamental beam and the preselected wavelength beam incident on said generator within 10 degrees of the Brewster angle for said generator; both said preselected wavelength beam and said fundamental beam incidenting on said on said generator at said preselected polarization;

g)   said fundamental beam reflected by said first resonator reflective surface back through said ~~nonlinear~~OPO nonlinear generator at said preselcted polarization to convert a second portion of said fundamental laser beam to preselected wavelength beam having the same preselected polarization as said—fundamental beam; said

preselected wavelength beam reflected by said OPO first reflective surface to oscillate said preselected wavelength beam_ in said OPO cavity;

i) a first beam separator in optical communication with said ~~nonlinear~~OPO nonlinear generator to separate said preselected wavelength beam from said fundamental wavelength beam after said second portion of said fundamental beam has been converted to preselected wavelength beam ;

j) fundamental beam directing means to direct said separated fundamental beam back through said lasing medium for further amplification;

k) preselected wavelength beam directing means for directing said separated preselected wavelength beam to said second OPO reflective surface where said beam is at least partially reflected back through said ~~nonlinear~~OPO nonlinear generator at said preselected polarization.

2. (original) The laser for providing a preselected wavelength according to claim 1 further comprising a Q-switch.

3. (original) The laser for providing a preselected wavelength according to claim 2 wherein said Q-switch is an acousto-optic Q-switch.

4.   (original)   The laser for providing a preselected wavelength according to claim 2 wherein said Q-switch is an electro-optic Q-switch.

5.   (original)   The laser for providing a preselected wavelength according to claim 2 wherein said Q-switch is a passive Q-switch.

6.   (original)   The laser for providing a preselected wavelength according to claim 5 wherein said passive Q-switch is a Cr^{+4}:YAG crystal.

7.   (currently amended)   The laser for providing a preselected wavelength beam according to claim 2 wherein said ~~nonlinear~~OPO nonlinear generator is ~~an~~a ~~nonlinear~~OPO nonlinear OPO crystal cut for noncritical phase matching

8.   (original)   The laser for providing a preselected wavelength beam according to claim 2 further comprising   l) an output coupler to remove a portion of said preselected wavelength beam outside said optical parametric oscillator cavity .

9.   (original)   The laser for providing a preselected wavelength beam according to claim 2 wherein said first OPO reflective surface and said first laser resonator reflective surface formed by a single mirror, said mirror highly reflective for fundamental beam and at least partially reflective for preselected wavelength beam.

10.   (original)   The laser for providing a preselected wavelength beam according to claim 7 wherein said first OPO reflective surface and said first laser resonator reflective surface formed by a single mirror, said mirror highly reflective for fundamental beam and at least partially reflective for preselected wavelength beam.

11.   (currently amended)   The laser for providing a preselected wavelength according to claim 7 wherein said ~~nonlinear~~OPO nonlinear crystal is a KTP, KTA, RTA, or RTP crystal.

12.   (original)   The laser for providing a preselected wavelength beam according to claim 11 wherein said lasing medium is a Nd:YAG, Nd:YLF, Nd:GdVO$_4$ or Nd:YVO$_4$ crystal.

13.   (original)   The laser according to claim 2 wherein said wavelength of preselected wavelength beam is an eyesafe wavelength.

14.   (original)   The laser according to claim 7 wherein said wavelength of preselected wavelength beam is an eyesafe wavelength.

15.   (original)   The laser according to claim 10 wherein said wavelength of preselected wavelength beam is an eyesafe wavelength.

16.   (currently amended)   The laser according to claim 13 wherein said lasing medium is Nd:YAG , or Nd:YVO$_4$ and said ~~nonlinear~~OPO nonlinear generator is a KTP or KTA crystal.

17.   (currently amended)   The laser according to claim 13 wherein said lasing medium is Nd:YLF and said ~~nonlinear~~OPO nonlinear generator is KTP or KTA crystal.

18.   (currently amended)   The laser for providing a preselected wavelength beam according to claim 2 wherein said ~~nonlinear~~OPO nonlinear generator is ~~an~~a ~~nonlinear~~OPO nonlinear OPO crystal cut for critical phase matching.

19.   (original)   The laser for providing a preselected wavelength beam according to claim 2 wherein said lasing medium is a Nd:YAG, Nd:YLF, Nd:GdVO$_4$ or Nd:YVO$_4$ crystal.

20.   (currently amended)   The laser for providing a preselected wavelength beam according to claim 11 wherein said ~~nonlinear~~OPO nonlinear generator is a KTA or KTP or RTA crystal.

21.   (currently amended)   The laser for providing a preselected wavelength beam according to claim 2 wherein said ~~nonlinear~~OPO nonlinear crystal is a KTP, KTA, RTA, or RTP crystal.

22.   (original)   The laser for providing a preselected wavelength beam according to claim 2 wherein said fundament and preselected wavelength beams incident on said generator within 5 degrees of the Brewster angle for said generator.

23.   (original)   The laser for providing a preselected wavelength beam according to claim 2 wherein said fundament and

preselected wavelength beams incident on said generator within 3 degrees of the Brewster angle for said generator.

24. (original) The laser for providing a preselected wavelength beam according to claim 2 wherein said fundamental and preselected wavelength beams incident on said generator at about the Brewster angle for said generator.

25. (original) The laser for providing a preselected wavelength beam according to claim 7 wherein said fundamental and preselected wavelength beams incident on said generator within 5 degrees of the Brewster angle for said generator.

26. (original) The laser for providing a preselected wavelength beam according to claim 7 wherein said fundament and preselected wavelength beams incident on said generator within 3 degrees of the Brewster angle for said generator.

27. (original) The laser for providing a preselected wavelength beam according to claim 7 wherein said fundament and preselected wavelength beams incident on said generator at about the Brewster angle for said generator.

28. (original) The laser according to claim 8 further comprising one or more harmonic generators in optical communication with said output coupler.

29. (original) The laser according to claim 8 further comprising a second harmonic nonlinear crystal in optical communication with said output coupler.

30. (original) The laser according to claim 29 further comprising a third harmonic nonlinear crystal in optical communication with said second harmonic crystal.

31. (original) The laser according to claim 30 further comprising a fourth harmonic nonlinear crystal in optical communication with said third harmonic crystal.

32. (original) The laser according to claim 28 wherein said harmonic generators are nonlinear crystals.

33. (original) The laser according to claim 2 further comprising a second harmonic generator located within said OPO cavity for generation of a second harmonic beam from said preselected wavelength beam.

34. (original) The laser according to claim 7 further comprising a second harmonic generator located within said OPO cavity for generation of a second harmonic beam from said preselected wavelength beam.

35. (original) The laser according to claim 34 wherein said second harmonic generator is a second harmonic nonlinear crystal.

36. (original) The laser according to claim 35 wherein second harmonic generator is located between said first OPO reflective surface and said first beam separator.

37. (original) The laser for providing a preselected wavelength according to claim 36 further comprising l) an output coupler to remove at least portion of second harmonic beam from said optical parametric oscillator cavity .

38. (currently amended) A laser providing a preselected wavelength comprising:

a) a laser resonator having a laser resonator cavity formed between a first laser resonator reflective surface and a second laser resonator reflective surface, said laser resonator having a resonator optical axis;

b) a Nd:YAG, Nd:YLF, Nd:GdVO$_4$ or Nd:YVO$_4$ lasing crystal located within said laser resonator cavity for generating a fundamental wavelength beam;

c) an optical parametric oscillator (OPO) cavity formed between a first OPO reflective surface and a second OPO reflective surface said optical parametric oscillator cavity having an oscillator optical axis which is in part separate from said resonator optical axis and which in part overlaps said resonator optical axis;

d) a noncritically phased matched ~~nonlinear~~OPO nonlinear crystal for OPO generation located within said OPO cavity along said oscillator optical axis and along said resonator optical axis in optical communication with said first and said second OPO reflective surfaces;

e) said noncritically phased matched ~~nonlinear~~OPO nonlinear crystal oriented to convert said fundamental wavelength beam into a preselected output wavelength beam having a preselected longer wavelength than said fundamental beam;

f) said optical axes intersecting opposed faces of said ~~nonlinear~~OPO nonlinear crystal; said opposed faces having a Brewster cut at the intersection of said ~~nonlinear~~OPO nonlinear crystal and said axes so that the fundamental beam and the preseleced output wavelength beam incident on said crystal within 10 degrees from the Brewster angle for said crystal;

<u>g) said fundamental beam and said preselected output wavelength beam both incident on said crystal at P-polarization;</u>

h~~g~~) said first resonator reflective surface reflective of fundamental wavelength beam and said first OPO reflective surface at least partially reflective of output wavelength beam so that fundamental and output beams reflected by said reflective surfaces propagate back through said ~~nonlinear~~OPO nonlinear crystal;

ih) a dichroic mirror located along the overlapping portion of said oscillator optical axis and said resonator optical axis between said ~~nonlinear~~OPO nonlinear crystal and said lasing medium; said dichroic mirror either highly reflective or highly transmissive for fundamental wavelength beam to direct said fundamental wavelength beam propagating from said lasing medium into said optical parametric oscillator cavity along said oscillator optical axis and through said ~~nonlinear~~OPO nonlinear crystal at P-polarization to convert a portion of said fundamental wavelength beam to a P-polarized preselected wavelength beam having a longer wavelength than said fundamental beam; said dichroic mirror directing fundamental beam reflected by said first resonator reflective surface back through said lasing medium for amplification and directing preselected output wavelength beam reflected by said first OPO reflective surface for at least partial reflection by said second OPO reflective surface.

39. (original) The laser according to claim 38 further comprising:

k) an output coupler in optical communication with said preselected wavelength beam to direct a portion of said preselected wavelength beam outside said optical parametric oscillator cavity as the laser output.

40.   (original)   The laser according to claim 38 wherein in h) said dichroic mirror is highly reflective for S-polarized fundamental beam and highly transmissive for preselected wavelength beam and further comprising I) a polarization rotator located between said dichroic mirror and said non linear crystal to rotate the polarization of said fundamental beam ½ wave .

41.   (original)   The laser according to claim 40 wherein said polarization rotator is a wave plate.

42.   (original)   The laser for providing a preselected wavelength beam according to claim 41 wherein said first OPO reflective surface and said first laser resonator reflective surface formed by a single mirror, said mirror highly reflective for fundamental beam and at least partially reflective for preselected wavelength beam.

43.   (currently amended)   A laser for providing a 193nm beam comprising:

a)   a laser resonator having a laser resonator cavity formed between a first laser resonator reflective surface and a second laser resonator reflective surface, said laser resonator having a resonator optical axis;

b)   a lasing medium   located within said laser resonator cavity for generating a fundamental wavelength beam;

c)   said lasing medium being a Nd:YAG or a Nd:YVO$_4$ crystal, producing a 1064nm fundamental beam or an Nd:YLF crystal producing a 1053nm;

d)   an optical parametric oscillator (OPO) cavity formed between said first OPO reflective surface and a second OPO reflective surface said optical parametric oscillator cavity having an oscillator optical axis which is in part separate from said resonator optical axis and which in part overlaps said resonator optical axis;

e)   an~~a~~ ~~nonlinear~~OPO nonlinear   generator for OPO generation located within said OPO cavity along said oscillator optical axis and along said resonator optical axis in optical communication with said first and said third reflective surface; said ~~nonlinear~~OPO nonlinear generator oriented to convert said 1064nm or 1053nm fundamental wavelength beam into an output wavelength beam having a wavelength of about 1544nm ;

f)   means to direct said fundamental wavelength beam into said optical parametric oscillator cavity along said oscillator optical axis and across said ~~nonlinear~~OPO nonlinear generator at P-polarization to convert a portion of said fundamental wavelength beam to a 1544nm output wavelength beam at P-polarization ;

g)   said optical axes intersecting opposed faces of said ~~nonlinear~~OPO nonlinear crystal;

said opposed faces having a Brewster cut at the intersection of said ~~nonlinear~~OPO nonlinear crystal and said axes so that the fundamental beam and about 1544 output wavelength beam incident on said crystal at P-polarization within 10 degrees from the Brewster angle for said crystal;

h)   said first laser resonator reflective surface reflective of fundamental wavelength beam; and said first OPO reflective surface at least partially reflective of output wavelength beam;

i)   means to direct said fundamental and output beams from said first laser resonator reflective surface and from said first OPO reflective surface back through said ~~nonlinear~~OPO nonlinear generator to form additional output wavelength beam;

j)   a beam separator to separate said 1544 output wavelength beam from said fundamental wavelength beam;

k)   fundamental beam directing means to direct said separated fundamental beam back through said lasing medium for further amplification;

l)   output beam directing means for directing said separated output wavelength beam to said second OPO reflective surface where said beam is at least partially reflected through said ~~nonlinear~~OPO nonlinear crystal;

m)   an output coupler to direct a portion of said 1544nm output wavelength beam on an output path outside said optical parametric oscillator cavity;

n)   a first, second harmonic generator located along said output path for converting a portion of said 1544nm beam to 772nm beam said first second harmonic generator delivering 1544nmbeam and 772 beam on a first second harmonic output path;

o)   a second ,second harmonic generator located along said first second harmonic output path, in optical communication with said first second harmonic generator for converting a portion of said 772nm beam from said first second harmonic generator to 386nm beam said second , second harmonic generator delivering 772nm beam and 386nm beam on a second, second harmonic output path ;

p)   a third harmonic generator(1w+2w=3w) located along said second, second harmonic output path, in optical communication with said second, second harmonic generator for converting a portion of said 772nm beam and a portion of said 386nm beam to 257nm beam said third harmonic generator delivering 772nm beam and 257nm beam on a third harmonic generator output path;

a fourth harmonic generator (1w+3w=4w) in optical communication with said third harmonic generator output path for

converting a portion of the 772nm beam and the 257nmbeam to a 193nm beam ;

said fourth harmonic generator delivering said 193nm on a fourth harmonic generator output path.

44.   (original)   The laser for providing a 193nm beam according to 43 further comprising a first polarization rotator located between said second, second harmonic generator and said third harmonic generator for rotating the polarization of either the 772nm beam or the 386nm beam ½ wave so that said 772nm beam and said 386nm beam have parallel polarization when passing through said third harmonic generator.

45.   (original)   The laser for providing a 193nm beam according to claim 44 further comprising a second polarization rotator located between said third harmonic generator and said fourth harmonic generator for rotating the polarization of either the 772nm beam or the 257nm beam ½ wave so that said 772nm beam and said 257nm beam have parallel polarization when passing through said fourth harmonic generator.

46.   (original)   The laser for providing a 193nm beam according to claim 45 further comprising a beam separator located on said fourth harmonic output path to separate said 193nm beam from other

beams of said laser and deliver said 193nm beam on a preselected output path.

47. (currently amended) The laser for providing a 193nm beam according to claim 46 wherein said ~~nonlinear~~OPO nonlinear generator is a KTP, KTA, RTA, or RTP crystal.

48. (original) The laser for providing a 193nm beam according to claim 47 wherein said first second harmonic generator is a KTP nonlinear crystal.

49. (original) The laser for providing a 193nm beam according to claim 48 wherein said second, second harmonic generator is a LBO nonlinear crystal.

50. (original) The laser for providing a 193nm beam according to claim 49 wherein said third harmonic generator is a BBO nonlinear crystal.

51. (original) The laser for providing a 193nm beam according to claim 50 wherein said fourth harmonic generator is a BBO nonlinear crystal.

52. (original) The laser for providing a 193nm beam according to claim 43 wherein said output coupler provides said first or said second OPO reflective surface.

53. (original)   The laser for providing a 193nm beam according to claim 52 wherein said output coupler is 3% to 40% transmissive of 1544nm beam.

54. (currently amended)   The laser for providing a 193nm beam according to claim 43 wherein said lasing medium is a YAG crystal and said nonlinearOPO nonlinear crystal is a KTP or KTA crystal.

55. (currently amended)   The laser for providing a 193nm beam according to claim 43 wherein the lasing medium is a Nd:YLF crystal and the nonlinearOPO nonlinear generator is a KTP crystal.

56. (currently amended)   A method of providing a preselected wavelength laser beam   comprising:

a)   forming a laser resonator having a laser resonator cavity formed between a first laser cavity reflective surface and a second laser cavity reflective surface, said laser resonator having a resonator optical axis;

b)   exciting a lasing medium located within said laser resonator cavity to generate a fundamental wavelength beam;

c)   forming an optical parametric oscillator (OPO) cavity between a first OPO –reflective surface and a second OPO reflective surface, said optical parametric oscillator cavity having an oscillator optical axis which is in part separate from said resonator optical axis and which in part overlaps said resonator optical axis;

d)   pumping ana ~~nonlinear~~OPO nonlinear generator for

OPO generation   located within said OPO cavity along said oscillator

optical axis and along said resonator optical axis in optical communication

with said fundamental beam _,said fundamental beam incidenting on said

~~nonlinear~~OPO nonlinear generator at P-polarization;

said ~~nonlinear~~OPO nonlinear generator oriented to

convert said fundamental wavelength beam into a P-polarized preselected

wavelength beam having a preselected longer wavelength than said

fundamental beam;

e)   directing said fundamental wavelength beam into

said optical parametric oscillator cavity along said oscillator optical axis

and through said ~~nonlinear~~OPO nonlinear generator to convert a first

portion of said fundamental wavelength beam to a preselected

wavelength beam having a longer wavelength than said fundamental

beam;

f)   said optical axes intersecting opposed faces of said

~~nonlinear~~OPO nonlinear generator; said opposed faces having a Brewster

cut at the intersection of said ~~nonlinear~~OPO nonlinear generator and said

axes so that the   fundamental beam and the preselected   wavelength

beam _ incident on said ~~nonlinear~~OPO nonlinear generator within 10

degrees from the Brewster angle for said generator;

g) reflecting said fundamental wavelength beam and at least partially reflecting said preselected wavelength beam back through said ~~nonlinear~~OPO nonlinear generator at P-polarization to oscillate said reflected preselected wavelength beam and to convert a second portion of said fundamental laser beam to preselected wavelength beam;

i) separating said preselected wavelength beam from said fundamental wavelength beam;

j) directing said separated fundamental beam back through said lasing medium for further amplification;

k) reflecting at least a portion of said separated preselected wavelength beam through said ~~nonlinear~~OPO nonlinear generator.